TRANSPARENT AND FLEXIBLE TACTILE SENSOR FOR MULTI TOUCH SCREEN APPLICATION WITH FORCE SENSING

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ABSTRACT

In this paper, we propose and demonstrate a transparent and flexible tactile sensor which is designed for multi touch screen application. The sensor module is composed of 2-D array capacitive tactile cells to measure the touch force on multiple positions. The device was fabricated with transparent materials on transparent plastic substrate. The touch input was measured by the capacitance variation resulting from the mechanical deformation of parallel plate capacitor.

KEYWORDS

Touch screen, tactile sensor, flexible device

INTRODUCTION

A touch screen is a display which can detect the presence and location of a touch within the display area. Currently touch screens, because they provides very intuitive user interfaces, are widely used not only in screens for computer system in inductry but also in hand-held devices such as mobile phone, PDA, and car navigation systems.

The important characteristics of touch screen which is utilized with display includes ; Transmittance, resolution, resistance to surface contamination, durability (life time), multi-touch recognition, display size, force sensing.

There are a number of types of sensing technology for touch screen. A resistive [1] and capacitive [2] detection methods have been widely used in conventional touch screens. But these types only recognize single touch point. Recently multi touch screens recognizing multiple simultaneous touch points are often associated with hand-held mobile devices such as Apple Inc's iPhone. There are several technologies for multi touch recognition. The patterned capacitive type involves transparent row and column electrodes arrays embedded within insulating material [7, 8]. The change of capacitance at finger touch points is monitored. Table 1 is comparison table of touch screen technologies.

The above mentioned touch screen technologies are well adopted to plat panel display. However nowadays many researches have been reported about flexible display because the plat pannel display using glass substrate is difficult to carry and easily broken [9, 10]. To be utilized in flexible display, the touch screen should also show flexible property. However, as seen in Table 1, most of the touch screens didn't show flexibility. So in this work, transparent and flexible tactile sensor which is designed for multi touch

Table 1. Comparison table for touch screen technologies

	Resistive	Capacitive	IR	SAW	DST	Strain gauge	Patterened capacitive
Transmittance(1)	Poor	Good	Good	Good	Very good	Very good	Poor
Multi touch(2)	No	No	No	No	NA(3)	No	Yes
Force sensing	No	No	No	NA	Yes	Yes	No
Flexibility	NA	NA	No	NA	NA	NA	NA
Input	Any materials	Finger	Any materials	Any materials	Any materials	Any materials	Finger
Reference	[1]	[2]	[3]	[4]	[5]	[6]	[7], [8]

While this table presents general characteristics of the different touch screen technologies, variations can occur in manufacturer-specific models.
(1) Poor <~90%, Good >90%, Very good >~97%
(2) Multi touch means the ability to recognize multiple touch points without limitation.
(3) NA : Not available from manufacturer or no enough information.

screen application.

Various tactile sensors with force sensing have been researched for the last years mainly for artificial skin for robot applications [11, 12], wearable computers [13], and mobile or desktop haptic devices [14]. But most of devices are not suitable for touch screen of display systems because of their non-transparency of materials.

In this paper, we propose and demonstrate a transparent and flexible tactile sensor which is designed for multi touch screen application.

DESIGN

Four popular pressure sensing mechanisms for tactile sensors have been reported: resistive, piezoresistive, piezoelectric, and capacitive sensing mechanisms. In resistive sensors, resistance change induced from squeezed resistive material between electrodes is measured [15]. A piezoresistive sensing mechanism uses strain gauge to measure deformation of a tactile cell [16]. A piezoelectric mechanism measures the accumulation charges and resulting voltage buildup as membrane is forced. But piezoelectric sensor cannot detect static force [17]. A capacitive sensing mechanism measures capacitance change induced from gap change between electrodes [11]. Among these mechanisms, a capacitive sensing mechanism has been used in this work because it is less susceptible to noise and immune to temperature change. In addition, capacitive sensor can detect static input.

Figure 1 show the cross-sectional view of proposed tactile sensor. Table 2 shows the parameter of proposed device. The two substrates (top and bottom plates) are transparent Polycarbonate (PC) films (120 µm thick). Thin transparent IZO layer was used for electrodes and signal line. The two electrodes forms a capacitor separated by 18 µm via SU-8 spacers. The cell size and electrode size are 2 × 2 mm^2 and 1 × 1 mm^2, respectively. Initial capacitance of one cell has been estimated as 611 fF assuming the relative permittivity of SU-8 as 3.2. When a touch pressure is applied on the surface of upper plate, the gap between two plates decreases and capacitance increases until the gap is closed. By measuring the capacitance for entire capacitive array cells, we can determine the touch position and applied force on multiple locations.

Table 2. Parameters of proposed device.

Parameters	Values
Thickness of top plate	120 µm
Spacer height	13 µm
Thickness of electrode	0.13 µm
Thickness of insulator	5 µm
Thickness of Bottom plate	120 µm
Electrode width (d_E)	1 mm
Gap between spacer (d_S)	1.8 mm
Width of single cell (d_C)	2 mm

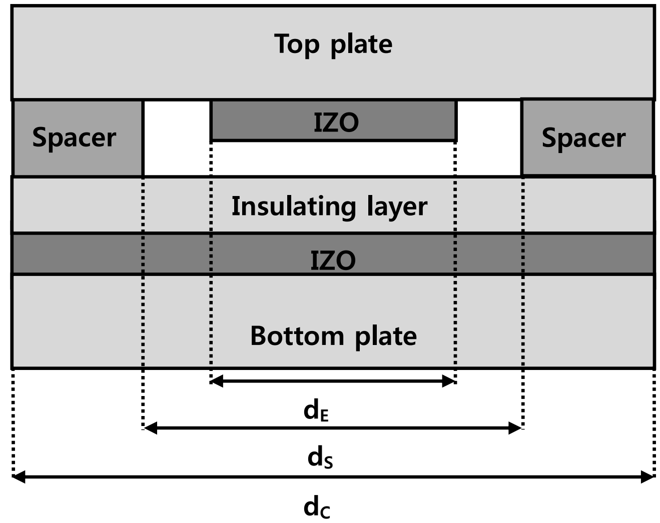

Figure 1: The cross-sectional view of tactile sensing unit cell and its dimensions.

FABRICATION

Fabrication process is shown in Figure 2. Each layer is processed separately and bonded together. We used IZO-coated polycarbonate (PC) film. For photolithography the films were mounted on silicon wafer. For top plate, first the IZO layer was patterned (Figure 2 (a)) using general photolithography and IZO etchant ($HCl:HNO_3$=3:1). Next, the SU-8 2007 (Microchem. Co) was patterned to form a 13 um height spacer on top substrate (Figure 2 (b)). For bottom plate the IZO layer was also patterned for bottom electrode (Figure 2 (c)). Next a thin SU-8 2005 (thickness of 5 µm) was spin-coated on bottom substrate to form insulation layer between top and bottom electrodes (Figure 2 (d)). Lastly, top substrate was aligned and bonded with bottom substrate to complete the sensor (Figure 2 (e)). Figure 3 shows the fabricated tactile sensor. The initial device was designed to have 20 × 20 capacitive cells and the size of entire sensor module is 6 × 6 cm^2 including interconnection pads. The fabricated sensor shows good flexibility as shown in the figures.

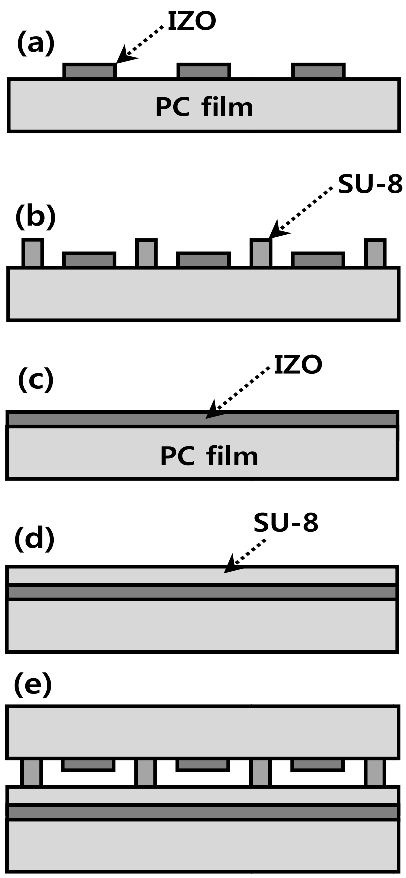

Figure 2: Process flow of a tactile sensor

EXPERIMENT AND RESULTS

Figure 4 shows the transparency of the fabricated tactile sensor on LCD display.

We set up custom-made equipment for touch force characterization because there is no commercial tool available for contact force measurement in a small scale. Fig. 5 displays our setup for contact force measurement. A force gauge with sharp tip has been used to apply a pressure on a specific capacitive cell precisely. This gauge has 1 mN resolution.

For read capacitance change on every cell, the readout circuitry has been designed to select every cell by row and column decoder. The readout analog signal is processed by custom-designed FPGA and final image was displayed by LabVIEW (NI).

A multi touch tactile images captured from the fabricated sensor are shown in Figure 6. The initial capacitance of a cell has been measured about 900 fF. There is saturation after 520 mN (520 kPa), which means both upper and bottom electrodes are in contact with an insulation layer between them.

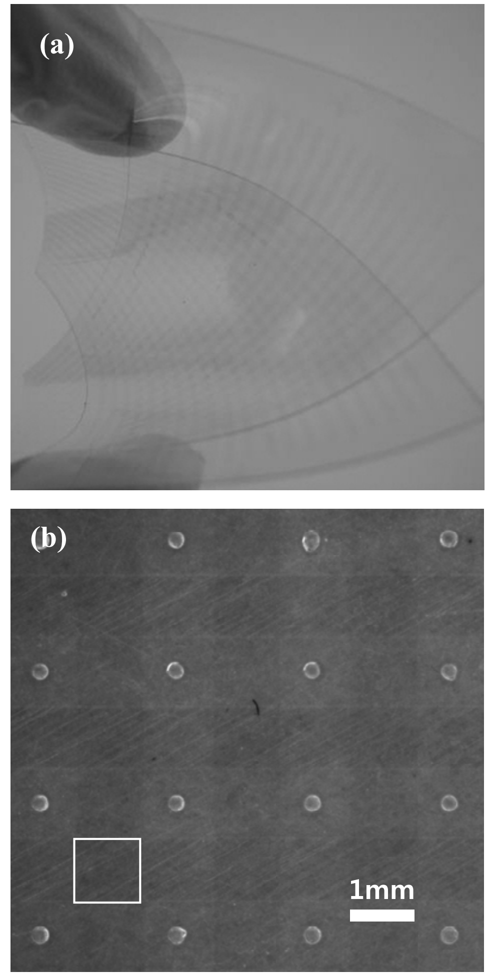

Figure 3: Fabricated tactile sensor. (a) Flexibility and (b) Magnified touch sensor.

Figure 4: Fabricated tactile sensor on LCD display.

Figure 5: The measurement setup.

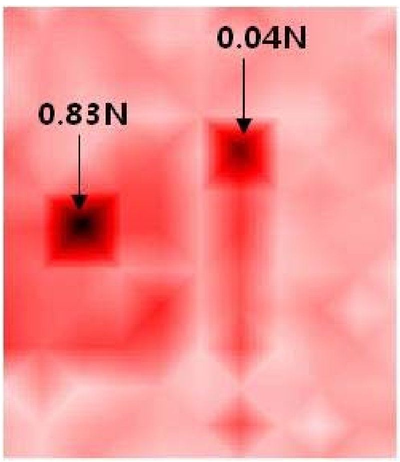

Figure 6: Multi touch tactile images captured from the fabricated sensor.

CONCLUSION

A sensor module consists of a 20×20 tactile cell array with 2 mm spatial resolution. The fabricated tactile sensor module shows good flexibility and captures multi touch images. Since the proposed tactile sensor modules are flexible and transparent, they can be a good candidate for touch screen for flexible display in the future.

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